

Effects of Induced Sputtering on $\delta^{13}\text{C}$ and Ar in the Martian Atmosphere

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Given the possibility of life having developed on Mars, it becomes important to know the environment that it evolved in. There is geomorphological evidence that the ancient climate was wetter and warmer. This environment was presumably created by a dense CO_2 atmosphere, but it leaves the fundamental question of what happened to the atmosphere. One possibility is that the atmosphere escaped to space. The main method for removing CO_2 is indirect sputtering, a process where the solar wind accelerates O^+ to high energies and then has them impact the upper atmosphere, causing them to eject other particles (see Luhmann and Kozyra, *JGR*, 1991). The primary constraint on sputtering and its effect on the atmosphere is the isotopic signature.

We have updated our Monte-Carlo model for sputtering (Kass and Yung, *Science*, 1995) with improved cross sections (from Johnson and Liu, *Science*, in press) and a more realistic handling of the dissociation of CO_2 . Using our new model, we find that Mars could have lost as much as a bar of CO_2 in the last 3.5 Gyr. This is sufficient CO_2 to allow a warmer and wetter climate to have existed during the early part of Mars' history. While there are large errors associated with the calculation due to uncertainties in modeling the evolution of the Sun, our modeling indicates (unlike Luhmann *et al.*, *JRL*, 1992) that sputtering can play a significant role in the evolution of the Martian atmosphere.

Using our new model, we considered the effects of the sputtering on the $\delta^{13}\text{C}$ and $^{36}\text{Ar}/^{38}\text{Ar}$ ratio of the Martian atmosphere. Using a simple model combining the effects of sputtering, outgassing (taken from Jakosky *et al.*, *Icarus*, 1994), carbonate formation (Stephens, *Caltech Thesis*, 1995) and polar reservoirs, we find that the model predicts values for the two isotopic systems in agreement with the current measurements for Mars. These two systems were chosen both because they are affected by relatively few processes and because they retain a record of the ancient atmosphere. We are currently expanding our work to also cover $\delta^{15}\text{N}$ and $^{20}\text{Ne}/^{22}\text{Ne}$. We hope to show that despite previous predictions (Jakosky *et al.*, 1994), it is possible to have large sputtering rates and recreate all the measured isotopic values.

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